

Pseudo Linear Gyro Calibration

by

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Previous high fidelity onboard attitude algorithms estimated only the spacecraft attitude and gyro bias. The desire to promote spacecraft and ground autonomy and improvements in onboard computing power has spurred development of more sophisticated calibration algorithms. Namely, there is a desire to provide for sensor calibration through calibration parameter estimation onboard the spacecraft as well as autonomous estimation on the ground.

Gyro calibration is a particularly challenging area of research. There are a variety of gyro devices available for any prospective mission ranging from inexpensive low fidelity gyros with potentially unstable scale factors to much more expensive extremely stable high fidelity units. Much research has been devoted to designing dedicated estimators such as particular Extended Kalman Filter (EKF) algorithms [1] or Square Root Information Filters [2].

This paper builds upon previous attitude, rate, and specialized gyro parameter estimation work performed with Pseudo Linear Kalman Filter (PSELIKA) [3]. The PSELIKA advantage is the use of the standard linear Kalman Filter algorithm. A PSELIKA algorithm for an orthogonal gyro set which includes estimates of attitude, rate, gyro misalignments, gyro scale factors, and gyro bias is developed and tested using simulated and flight data. The measurements PSELIKA uses include gyro and quaternion tracker data.

The use of PSELIKA hinges on the ability to express the nonlinear dynamics and measurement models expressed respectively in Eqs. (1.a) and (1.b)

$$\dot{\mathbf{x}} = \mathbf{f}(\mathbf{x}) + \mathbf{w} \quad (1.a)$$

$$\mathbf{y} = \mathbf{h}(\mathbf{x})\mathbf{x} + \mathbf{v} \quad (1.b)$$

in the form shown in Eqs. (2.a) and (2.b), respectively.

$$\dot{\mathbf{x}} = \mathbf{F}(\mathbf{x})\mathbf{x} + \mathbf{w} \quad (2.a)$$

$$\mathbf{y} = \mathbf{H}(\mathbf{x})\mathbf{x} + \mathbf{v} \quad (2.b)$$

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Equations (2) constitute the model used by the ordinary linear Kalman filter. The \mathbf{x} used in the F and H of Eqs. (2) is the best current estimate of the state vector, \mathbf{x} . The assumption behind PSELIKA is that the $F(\mathbf{x})$ and $H(\mathbf{x})$ will be reasonably close to the true values.

A simulation was developed for a spacecraft sensor complement of a 3-axis orthogonal gyro and quaternion tracker. The spacecraft attitude profile was rotated about x , y , and z axes respectively in order to render the gyro calibration parameters observable (see Fig. 1). The simulated gyro data was corrupted with misalignments of 0.01 radians, scale factor errors of 10,000 ppm (parts per million), and biases of 0.001745, -0.003491, and 0.005236 radians/sec respectively. The gyro calibration parameter estimation results are shown in Figs. 2-4. Better than 90% of the resulting gyro calibration parameters were estimated

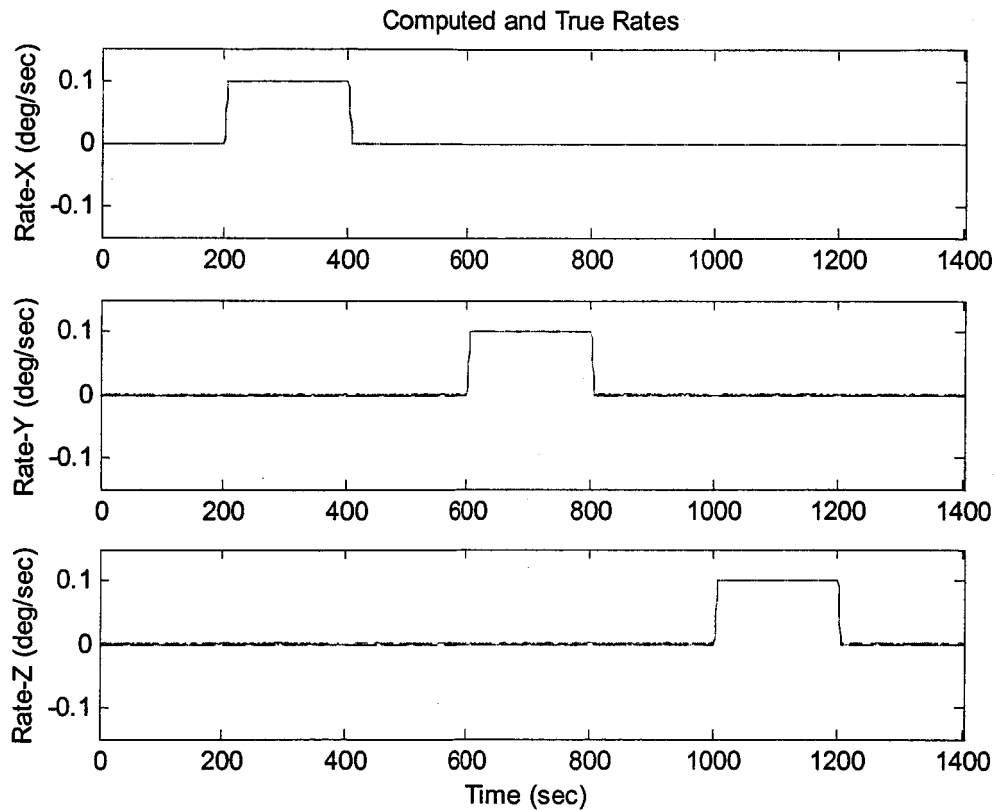


Figure 1: True (black) and Estimated (red) Rate Estimates

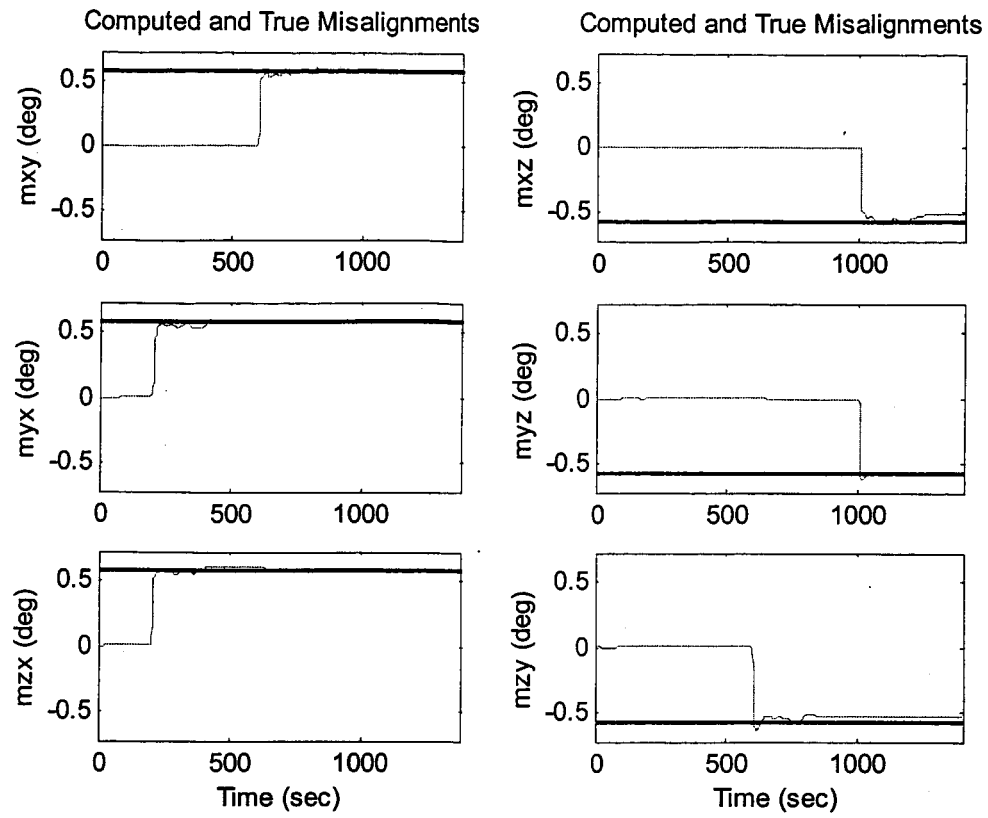


Figure 2: True (black) and Estimated (red) Gyro Misalignments

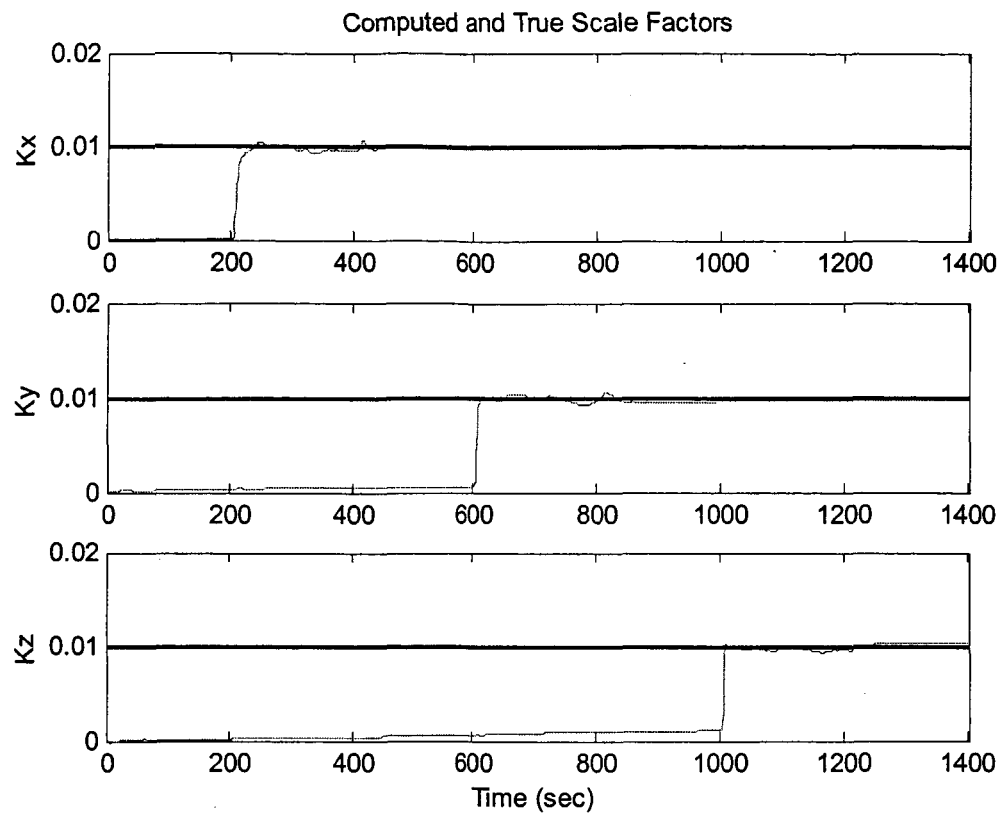


Figure 3: True (black) and Estimated (red) Gyro Scale Factors

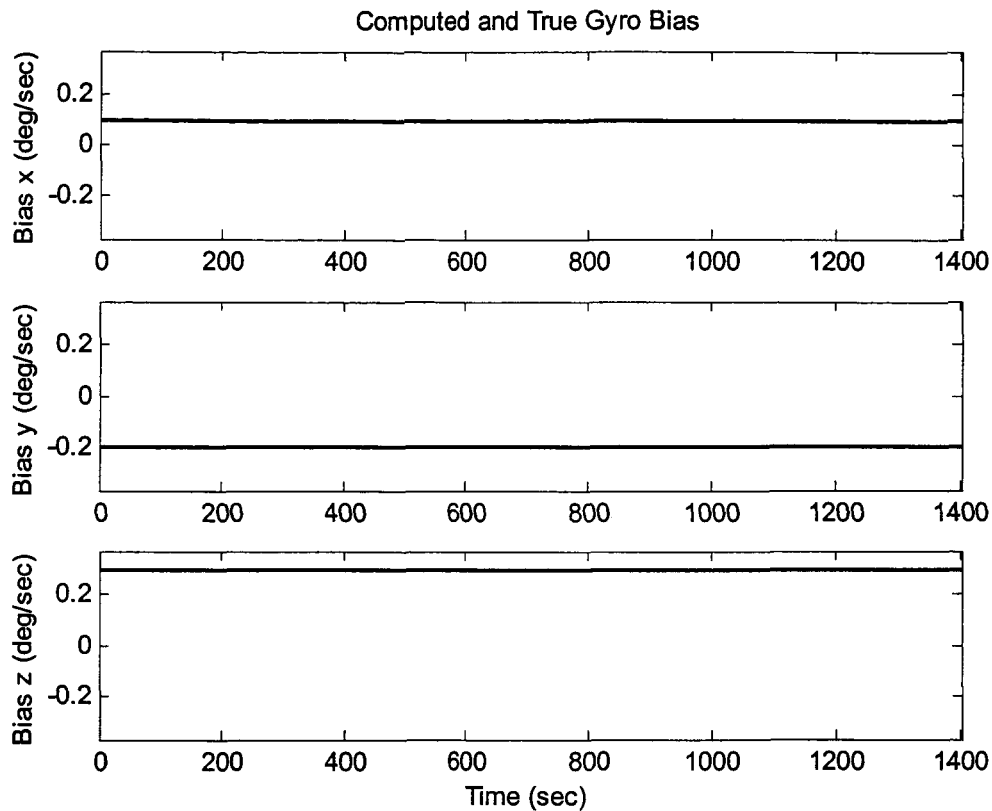


Figure 4: True (black) and Estimated (red) Gyro Bias

The full paper will present the estimates of the gyro calibration parameters for the Rossi X-Ray Timing Explorer (RXTE) spacecraft, which has two CCD star trackers along with a high fidelity orthogonal gyro package.

References

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- ² Johnson, W. and Phillips, R. "Stellar/Inertial (EBCCD/MEMS) Attitude Measurement and Control of all Small Satellites," Albuquerque, NM, August 28-30, 2001, Sponsored by AIAA. (Draper Report no. P-3896).
- ³ Bar-Itzhack, I.Y., Harman, R.R., and Choukroun, D., "State-Dependent Pseudo-Linear Filters for Spacecraft Attitude and Rate Estimation," AIAA Guidance, Navigation, and Control Conference, 5-8 August 2002, Monterey, California, Paper No. AIAA 2002-4461.